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INVESTIGATION OF ADHESIVE BONDING OF POLYPROPYLENE.(U)

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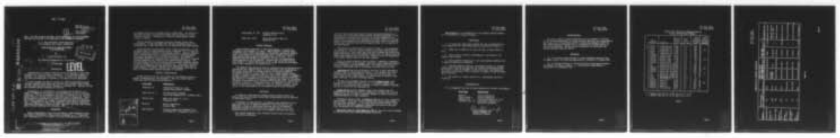

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U. S. Navy Underwater Sound Laboratory
Fort Trumbull, New London, Connecticut

INVESTIGATION OF ADHESIVE BONDING OF POLYPROPYLENE

by

Daniel Dinsmore, Jr.

USL Technical Memorandum No. 2133-214-67

10 March 1967

USL-TM-2133-214-67

INTRODUCTION

Polypropylene is a plastic material that was developed to have high resistance to a wide variety of chemicals. It is relatively immune to solvents, and, therefore, difficult to bond to itself with adhesives; any bond so accomplished is believed to be almost entirely mechanical.

A high-strength bond may be obtained by welding polypropylene parts together; commonly-used methods are hot gas torch welding, spin welding, and the Cosom hot platen weld discussed in reference (a). However, for all three methods special equipment is required.

Consequently, it is desirable to investigate the properties of a number of adhesives which might be used successfully in lieu of welding techniques. The use of adhesives can result in savings of both time and money; however, the limitations of adhesives must be understood. Information herein is presented in an effort to aquaint potential users with the various properties of a number of adhesives when used with polypropylene. A comparison is made of the adhesives' bond strength, elasticity (and shock resistance), effects of water immersion, and cure time requirements; bonding techniques are discussed, also.

BACKGROUND

Hollow polypropylene forms, such as spheres, right hexagonal prisms, and rhombic dodecahedrons, having outside diameters up to 5 inches and wall thicknesses up to 1.3 inches, are being investigated by USL for use

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as buoyancy objects at sea depths down to 30,000 feet. In practice, a buoy would be made up of multiple buoyant objects placed in a free-flooding container. (Reference (b) discusses polypropylene buoyant objects in detail.)

Various methods of producing the hollow buoyancy objects were investigated. It was determined that the most economical method of production was to mold the objects in two halves and bond them together.

Since methods of bonding were a part of this investigation, it was determined that the Cosom welding process (reference (a)) is ideal for quantity production bonding of the buoyancy objects. However, adhesive bonds, although much lower in strength and prone to handling damage, are equally satisfactory for certain applications. For example, preliminary hydrostatic pressure tests of buoyancy objects, to determine collapse pressures, are conducted with adhesive-bonded objects. The only limitations are that the objects must be handled carefully and may be used, normally, for only one pressurization. The primary advantage of the use of adhesives is the time saved; newly-molded parts may be bonded together "in house", whereas, for Cosom welding, parts must be sent to locations where special equipment is available.

ADHESIVE IDENTIFICATION

During the course of the test program for the buoyancy objects, a number of adhesives have been evaluated. They are listed below by trade name identification and manufacturer:

Trade Name	Manufacturer
Armstrong A-2	Armstrong Products Co., Inc. Argonne Road, Warsaw, Indianna
Teflon Kit No. 2	The Fluorocarbon Company, 1754 South Clementine St., Anaheim, Calif.
Plastic Lead	Magic Iron Cement Co., Inc., Cleveland, Ohio
Devcon F	Devcon Corporation, Danvers, Mass.
PRC PR-380-M	Products Research and Chemical Corp., 410 Jersey Ave., Gloucester City, N. J.

Black Magic No. 59M	Miracle Adhesives Corp., Bellmore, N. Y.
Walsco No. 56-02	Walsco Electronics Mfg. Co., Rockford, Ill.

BONDING TECHNIQUE

Proper surface preparation of the polypropylene, to provide for reasonable bond strength, is a must. Where possible, surfaces should be machined flat, and/or hand-lapped on medium-grit waterproof abrasive paper, to eliminate oily machining glaze and to roughen the surface; this lapping operation may be performed either wet or dry. It is essential that the surfaces be absolutely oil-free (no fingerprints) before application of the adhesive. Surfaces may be further cleaned with either W. T. Beam's Metal Conditioner or the sodium treating agent such as that included in the Teflon Kit No. 2.[1]

The adhesive used should be mixed in accordance with the manufacturer's instructions and applied thinly to both surfaces of the polypropylene. The pieces should then be clamped together with moderate pressure, preferably by means of a jig, clamp, or vise. Enough pressure should be used to obtain a relatively thin glue joint (this a matter of judgment), avoiding excessive pressure, which might extrude the adhesive completely and result in a "starved" glue joint. Suggested cure times for the various adhesives (not necessarily in accordance with manufacturers' instructions) are shown in Table II. Temperatures above 160 degrees F. should not be used for accelerated cure schedules, since the thermal expansion coefficients of the polypropylene and the adhesives may be quite different.

DISCUSSION

It should be noted that all bonding results reported herein are based on the use of Hercules Profax #6523 polypropylene with an additive of 2-½% carbon black.

As applied to hollow spheres, the adhesives were evaluated in four ways (the first two of which are measures of the elasticity of the adhesives): first, by hydrostatic pressure tests of the spheres, producing deformation of the bond due to plastic yield of the polypropylene; second, by drop tests of the spheres from table-top level

1 The limited comparison tests conducted between these two cleaners have been inconclusive.

to floor level, again with resulting shocks producing deformation of the bond, but in an elastic manner; third, and most significant of the evaluations, by tensile tests, in which the joined hemispheres were pulled apart on a tensile test machine; and fourth, evaluation by examination of the adhesive after hydrostatic pressure tests, to determine whether water immersion had had any apparent effect on its adhesion to the polypropylene.

The results of tensile tests are shown in Table I. For comparison, the results of a test on a sphere bonded by the Cosom welding process are also given; for this test, the actual bond strength was really much higher than shown, since considerable distortion of the sphere under the high loading occurred prior to failure. Distortion was not significant at the lower failure loads for the other spheres.

Table II, which is based in part on Table I, presents a comparison of the adhesives for bond strength, elasticity, water immersion effects, cure requirements, and recommended uses. The adhesives are rated by listing in descending order of usefulness (the best is at the top).

Armstrong A-2 has been the adhesive used most in USL's hydrostatic pressure tests of hollow buoyancy objects. It is reliable for tests involving only one pressurization. For certain long term tests, in which there is only a small amount of plastic creep, an object's bond may be expected to survive de-pressurization.

The last two statements also hold true with Plastic Lead, which is rated third (below Teflon Kit No. 2) for general purpose use, because of its much lower bond strength; its shock resistance, although low, is on a par with the Armstrong A-2.

Teflon Kit No. 2 has a somewhat higher bond strength than the Armstrong A-2, but is rated below it because it is more prone to shock damage and because its bond is degraded somewhat by water; survival of de-pressurization is a rare occurrence.

Preliminary tests, to date, on Devcon F indicate it to be a promising bonding agent. (Note that it has a considerably higher bond strength than the other adhesives.) It is rated fourth only tentatively, since its elasticity and water immersion characteristics have not yet been fully investigated for comparison purposes.

Walsco No. 56-02 and Black Magic No. 59M are very low in bond strength but are very good under shock and flexing conditions.

PRC PR-380-M is not recommended for any adhesive purpose because of its extremely low tensile strength.

CONCLUSIONS

1. All adhesives tested have limited use, due to relatively low bond strength and the other characteristics indicated in Table II.

2. Armstrong A-2 adhesive is rated the best of those tested to date.

3. Devcon F merits further investigation on the basis of its highest bond strength.

4. Proper surface preparation of the polypropylene material prior to applying adhesives is essential.

5. Although adhesive bonds are considerably inferior to thermal-welded bonds, they are satisfactory for certain limited applications and require no special equipment to make the bonds. When used, with intelligent discretion, in lieu of welding, economies in time and money may be effected.

6. The search for a better adhesive for polypropylene should be continued.

RECOMMENDATION

It is recommended that the following adhesives be further investigated:

Trade Name	Manufacturer
Devcon F	Devcon Corporation
Plastic Steel A	Devcon Corporation
Armstrong C-7	Armstrong Products Co., Inc.
Lefkoweld Type 109	Leffingwell Chemical Co. Whittier, California

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ACKNOWLEDGEMENT

The writer wishes to express appreciation to Mr. Dominic C. Colonni for his personal assistance in finding suitable adhesives for polypropylene; and, also, for his considerable effort in preparing hemisphere bonds and then conducting bond strength tests to determine the relative merits of the various adhesives. He was further responsible for developing the bonding technique reported herein.

REFERENCES

(a) "A Low-Cost Buoyant Element for Deep-Submergence Applications," by Seymour Gross, USL Technical Memorandum No. 933-60-65 of 3 March 1965.

(b) "A Bonding Technique for Producing Hollow Polypropylene Spheres and Prisms," by Daniel Dinsmore, Jr., USL Technical Memorandum No. 933-466-65 of 22 September 1965.

TENSILE TEST RESULTS ON ADHESIVE BONDS OF
HOLLOW POLYPROPYLENE SPHERES

Sphere Serial No.	Adhesive	Failure Load (lb.)	Bond Area (sq. in.)	Bond Tensile Strength (psi)	Bond Tensile Strength Average
* B 69/70	Armstrong A-2	1700	7.13	238	
* A 27/28	Armstrong A-2	900	5.5	164	
A 55/56	Armstrong A-2	1100	5.5	200	191
A 57/58	Armstrong A-2	800	5.5	145	
A 59/60	Armstrong A-2	1150	5.5	209	
A 287/288	Plastic Lead	750	5.5	136	
A 46/282	Plastic Lead	1000	5.5	182	
A 300/301	Plastic Lead	600	5.5	109	118
A 302/303	Plastic Lead	400	5.5	73	
A 304/305	Plastic Lead	500	5.5	91	
A 7/9	Teflon Kit No.2	1400	5.5	255	
A 1/4	Teflon Kit No. 2	1000	5.5	182	
A 294/295	Teflon Kit No.2	1100	5.5	200	218
A 296/297	Teflon Kit No.2	1100	5.5	200	
A 298/299	Teflon Kit No.2	1400	5.5	255	
A 7/9	Walsco No. 56-02	500	5.5	91	91
A 1/4	Walsco No. 56-02	500	5.5	91	
B 71/72	Black Magic No. 59M	500	7.13	70	
B 79/80	PRC PR-380-M	125	7.13	18	
A 294/295	Devcon F	1500	5.5	273	
A 296/297	Devcon F	1500	5.5	273	273
A 298/299	Devcon F	1500	5.5	273	
A 298/299	Devcon F	1500	5.5	273	
A 269/270	Cosom Welded	3500	5.5	635	

* B spheres have an O.D. of 4¼" and an I.D. of 3".
* A spheres have an O.D. of 4" and an I.D. of 3".

TABLE I

COMPARISON OF ADHESIVE PROPERTIES

Adhesive	Bond Strength, Ave. Tensile (PSI)	Elasticity	Adherence After Water Immersion		Cure Time		Recommended Use
			Short Term	Long Term	Room Temp.	Heat	
Armstrong A-2	191	Poor	Unaffected	Unaffected	1 Week	2 Hours	General Purpose
Teflon Kit No. 2	218	Poor	Slightly Degraded	Poor	24 Hours	--	General Purpose Dry Use Only
Plastic Lead	118	Poor	Unaffected	Unaffected	12 Hours	--	General Purpose
Devcon F Alum. Putty	273	Poor	Unaffected	No Data	4 Hours	Varies	General Purpose
Walsco No. 56-02	91	Very Good	Unaffected	No Data	12 Hours	--	Shock and Flexing
Black Magic No. 59M	70	Very Good	Unaffected	No Data	12 Hours	--	Shock and Flexing
PRC PR-380-M	18	Fair	Unaffected	No Data	72 Hours	6 Hours	Not Recommended

TABLE II